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Hot Water Making Potential Using of a Conventional Air-Conditioner as an Air-Water Heat Pump

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Abstract

Heat pumps denote a novel technology with great potential to decrease the energy consumption in many industries. It is a device that removes heat from the source at low temperature to the sink at high temperature by using mechanical work. Normally, it uses the same basic refrigeration cycle. However, the difference between a heat pump and a conventional air conditioner is that a heat pump can be used to provide heating or cooling by using a reversing valve. The objective of the present study is to investigate the potential of hot water producing by using a conventional air conditioner as air-water heat pump. Air conditioner with cooling capacity of 1 TR and working with R-22 was used in this study. The room temperatures were adjusted at the range between 21-25 ^{o}C and the hot water temperatures were kept at 40, 45 and 50 ^{o}C, respectively. The water cooled condenser was immersed in the hot water tank with 40 liters capacity. All experimental data were measured at steady state condition. COP of the heat pump system is compared with the conventional air conditioner. Moreover, the effect of setting room temperature and setting hot water temperature on the COP, time interval for making of 200 L hot water, power consumption at compressor and equivalent energy required for 200 L hot water making are presented.

Keywords: Air-conditioner ; Air-water heat pump; Power consumption; COP

1. Introduction

Normally, heating and cooling systems are widely used in comfort air conditioner and industrial applications. However, the share of the energy for heating and cooling purposes in total energy consumption increases. Due to the economical benefits resulting from high coefficient of performance (COP) values, mechanical heat pump systems become convenient devices for heating and cooling purposes [1], [2]. Heat pump is an apparatus or machine that moves heat from the heat source at a lower temperature to the heat sink at a higher temperature by means of mechanical work or a high temperature heat source [3]. The difference between a conventional a conditioner and a

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heat pump is that a heat pump can be used to provide heating or cooling. However, heat pump is still uses the same basic refrigeration cycle for working. It can be easier to say that a heat pump can change which coil is the condenser and which the evaporator by using a reversing valve.

So, in cooling conditions, it is common to require heat pumps that are designed only to provide heating. Now a day, the cost of energy continues to rise and it becomes a imperative to save energy and improve overall energy efficiency. A key idea for improving the energy efficiency of many industries is to recover every possible sources of waste heat and convert this energy to a useful output [4]. Moreover, many efforts tried to increase the heat pump performance. However, this study is aimed to investigate the hot water making potential by using the waste heat that released from condenser of the air conditioner. The advantages of this system are as follows: 1) Save energy due to use of the waste heat to produce hot water 2) Without electric short circuit and 3) Fast to produce hot water and 4) Reduce green house gases [5]. So, some recent researches focused on this area are summarized as follows:

Roongutai et al. [6] studied the warm water making from air-conditioning system by using of the waste heat that released from the air-conditioner. A pressure switch was used to activate both of the condensers, which are automatically controlled. Their results indicated that the highest temperature of the water in the reservoir is 49 ^{o}C

Saisanit et al. [7] design and construct the prototype of the hot water making machine using waste heat released from a common air conditioner system. Two types of the hot water system such as “submerged coil” and “flow through” are used in their study. Solenoid valves were used to control the flow direction of the refrigerant. Air conditioner with cooling capacity of 3 TR and working with R22 was used in this study. The result indicated that the hot water making machine with submerged coil type is more appropriate to use than the flow through type.

As mentioned before, the purposes of this study are to investigate the potential of hot water making by using a conventional air conditioner as an air-water heat pump and then to compare the COP of the system between conventional air conditioner cycle and heat pump cycle. The energy saving potential for making of 200 L hot water is also presented.

2. Experimental Apparatus and Procedure

Fig.1 shows schematic diagram of the experimental apparatus. It mainly consists of a evaporator, air cooled condenser, water cooled condenser, compressor, capillary tube, reservoir tank, solenoid valves and feed water valve. The air conditioner with cooling capacity of 12,000 Btu/h is used as a common cycle. Then, a water cooled condenser is added into the system for working as a heat pump. Evaporator is placed in the control room with dimension of 3x3x2.5 m. Room temperature is kept at 21, 23 and 25 ^{o}C. Solenoid valves are used to change the flow direction of refrigerant. In the present study, refrigerant R-22 is used as a working fluid. The bourdon pressure gage and T-type thermocouple are mounted at the both ends of the evaporator, air cooled condenser and water cooled condenser to measure pressure and refrigerant temperature, respectively. Similarly, YOKOGAWA power-meter model 2041 is used to measure power consumption at compressor. Focused on the water cooled condenser, the coil made from copper tube is immersed in the hot water tank with volumetric capacity of 40 liters. This tank made from stainless steel. T-Type thermocouple with temperature controller is used to control the hot water temperature. The temperature of hot water is adjusted at 40, 45 and 50 ^{o}C. When the required value of temperature is reached, the tank thermostat switched the unit off. A floating valve and solenoid valve is used to control water level in the tank. Similarly, reservoir tank with capacity of 200 liters is used to store hot water that leaving from the hot water tank. Feed water valve is used to supply make up water to the hot water tank.

In this study, the bourdon pressure gages were calibrated by the manufacturer. Similarly, all measuring temperature devices are well calibrated in a controlled temperature bath using standard precision glass thermometer. The uncertainty of all temperature measurement after considering the data acquisition system is $\pm$ 0.1 ^{o}C.

During the test run, pressure and temperature at the inlet and exit of evaporator and condensers, power consumption at compressor were recorded under the steady state operating condition.

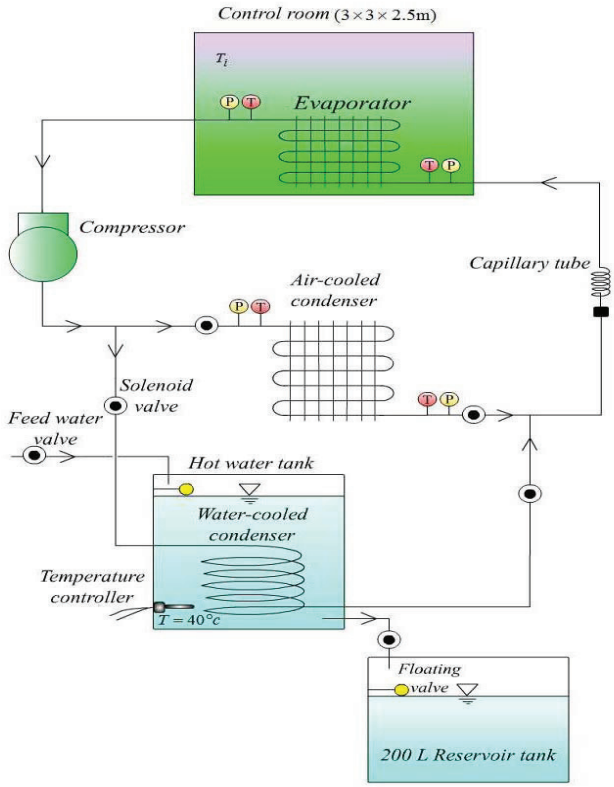

Fig. 1. Schematic diagram of the experimental apparatus

Data Reduction

In order to study the hot water making potential of the heat pump system and then compare of the COP between common cycle and heat pump cycle, the important parameters can be calculated from following equation.

- Cooling capacity at evaporator (Q_{Evap})

$$Q_{Evap} = (h_1 - h_4) \tag{1}$$

- Compressor work (W_{Comp})

$$W_{Comp} = (h_2 - h_1) \tag{2}$$

- Coefficient of performance (COP)

$$COP = \frac{Q_{Evap}}{W_{Comp}} \tag{3}$$

where h_1 and h_2 are the enthalpy at inlet and exit of compressor, respectively. h_4 is the enthalpy at inlet of evaporator.

3. Results and Discussion

The following experimental results showed the comparison of COP between conventional air conditioner system and the heat pump system at various hot water temperature and room temperatures. Moreover, time period for making of 200 liters hot water is presented. The results were depicted in the following sub-section.

Fig.2 shows comparison of COP between common A/C cycle and heat pump cycle. The results show that COP of common cycle gives a slightly higher than the heat pump cycle and COP increases with an increasing room temperature. This is because when the required temperature is reached, continuous flow of the refrigerant through the coil still takes place which lead to increase in condensing temperature as well as power of the compressor.

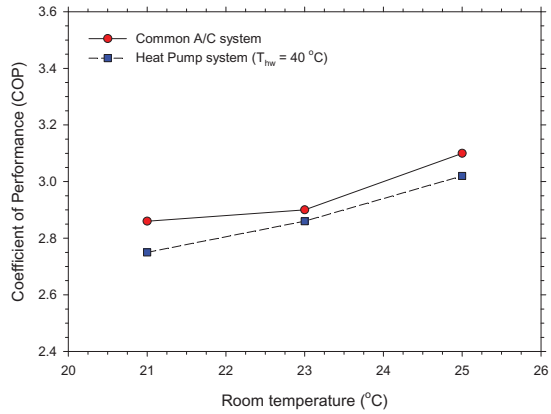

Fig. 2. Comparison of the COP between conventional air conditioner cycle and the heat pump cycle

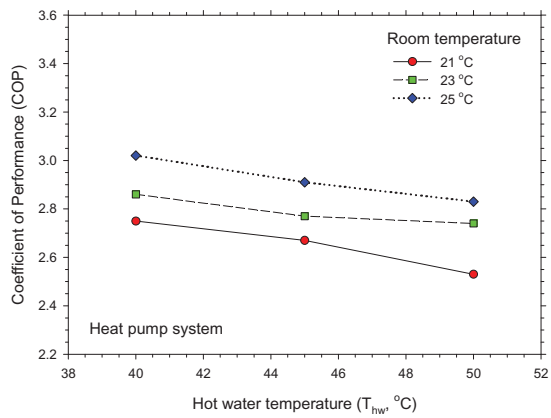

Fig. 3. COP of the heat pump system as a function room temperature and hot water temperature

Fig. 3 shows the effect of hot water temperature on the COP of heat pump cycle with different room temperatures. It clearly seen that the COP decrease with increasing hot water temperature, because increasing the hot water temperature leads to an increase in the compressor power which results in an decrease in the COP of the system.

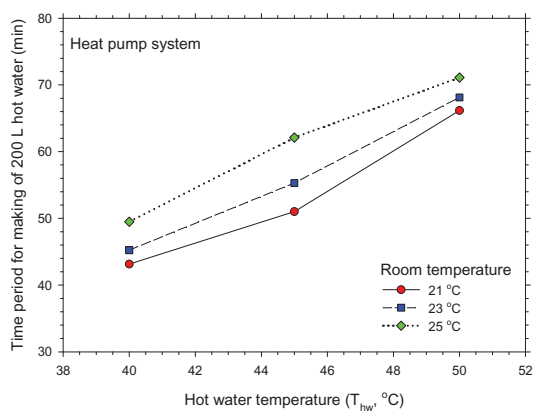

Fig. 4. Time interval requirement for making of 200 L hot water as a function of hot water and room temperature

Fig. 4 shows the variation of the time period for making of 200 L hot water as a function of hot water temperature. As shown in this figure, the results show that time period increases with increasing hot water temperature as well as setting room temperature. This is due to increasing the hot water temperature leads to an increase in the time period for making of hot water.

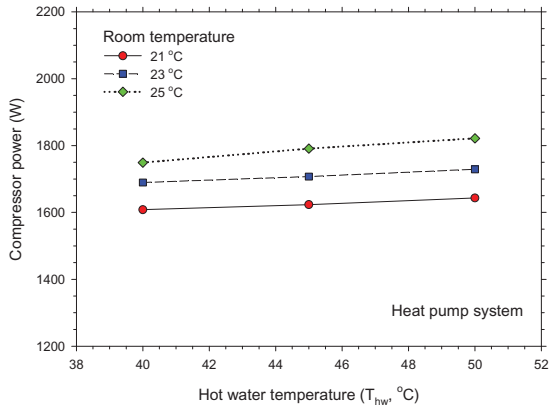

Fig. 5. Compressor power as a function room temperature and hot water temperature

As shown in Fig. 5, the power consumption of compressor increases with increasing the hot water temperature as well as room temperature. This is due to the fact that increasing in the hot water temperature in the reservoir tank lead to increase in the condensing temperature. So, high power consumption of the compressor is obtained. Similarly, an increase of the setting room temperature leads to increase in the evaporating temperature and condensing temperature at the same time.

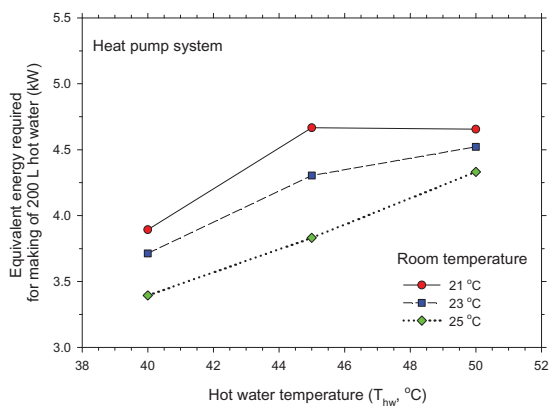

Fig. 6. The equivalent energy required for making of 200 L hot water at various room temperatures and hot water temperatures

Fig. 6 illustrates the equivalent energy required for making of 200 L hot water at various room temperatures and hot water temperatures. The results indicated that modifying of the conventional air conditioner as a heat pump for making of hot water can save the electric energy from 3.5 to 4.5 kW depend on the operating conditions. This is because the waste heat at condenser were recovered and used to provide hot water instead of the electric heater. This means that the hot water produced from this system is free. For example, at 45^{o}C hot water temperature and 25^{o}C

room temperature, the heat energy obtained from 200 L hot water making is about 3.7 kW. However, this energy obtained from waste heat at condenser without use of the electric power. This is an important advantage of this system.

4. Conclusion

The hot water making potential by use of the common air conditioner as an air-water het pump was experimentally investigated. Experiments were carried out on the COP and then compare between conventional system and heat pump system. The effect of setting room temperature and setting hot water temperature on the COP, time interval for making of 200 L hot water, power consumption at compressor and equivalent energy required for 200 L hot water making are determined. Important conclusions have been obtained and are summarised as follows:

- COP of the common A/C cycle is slightly higher than the heat pump cycle.
- COP of both systems decrease with increasing hot water temperature and decreases with decreasing room temperature.
- time interval for making of 200 L hot water increases with increasing hot water temperature and room temperature.
- Similarly, the energy consumption of compressor increases with increasing the hot water temperature as well as room temperature.
- modifying of the common air conditioner as an air-water heat pump for making of hot water can save the electric energy from 3.5 to 4.5 kW depend on the operating conditions.

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